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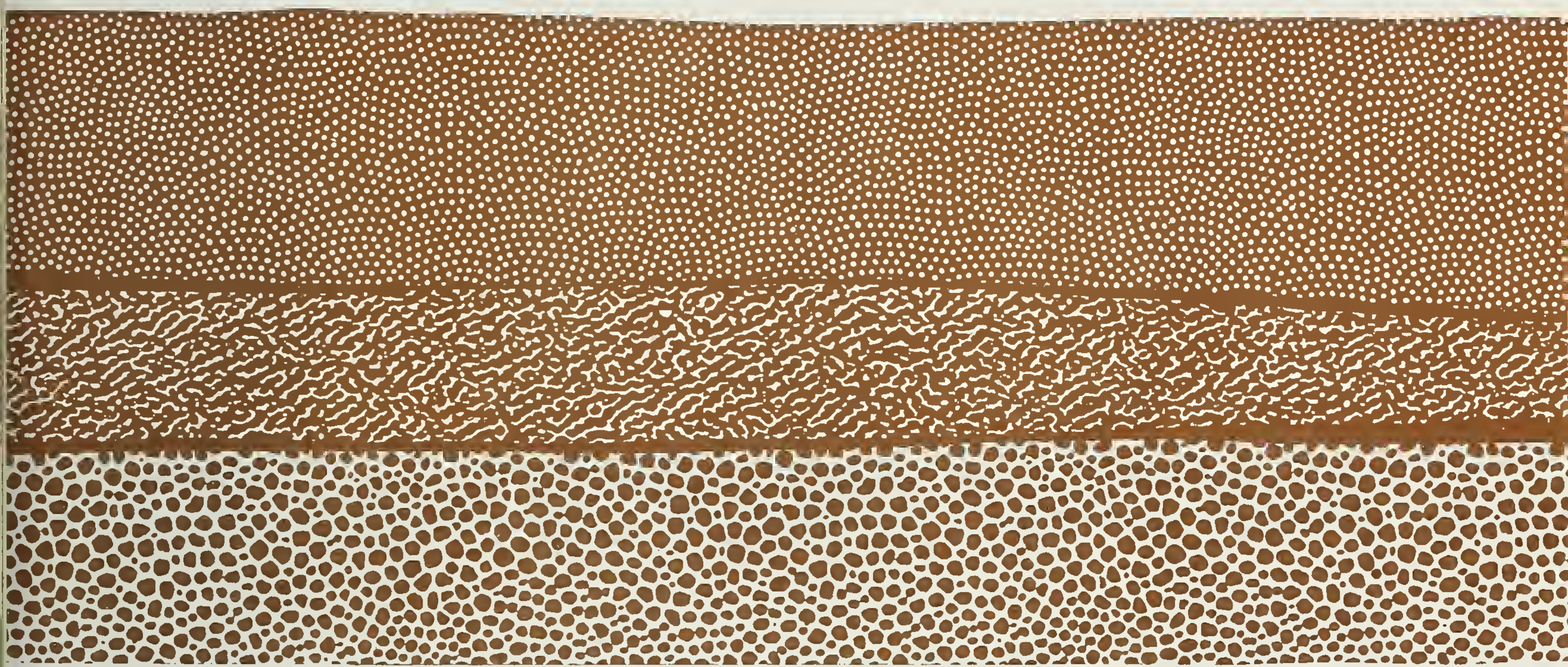
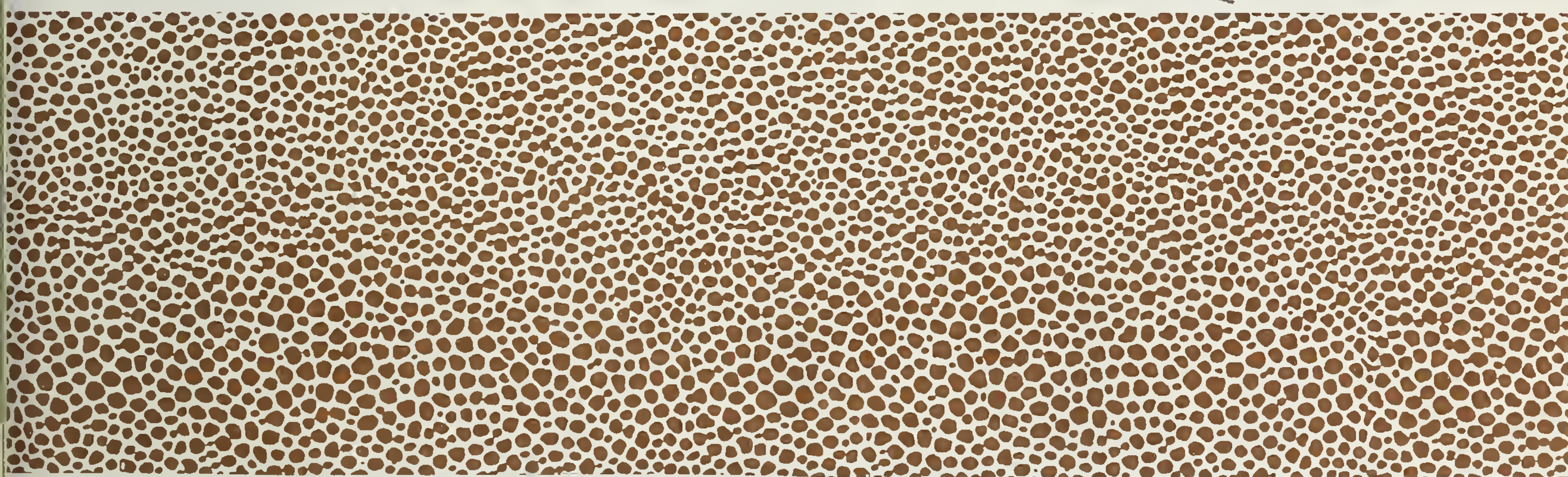
PHYSICAL and CHEMICAL PROPERTIES of some BLUE MOUNTAIN SOILS in NORTHEAST OREGON



J. MICHAEL GEIST and GERALD S. STRICKLER



PACIFIC NORTHWEST FOREST and RANGE EXPERIMENT STATION
FOREST SERVICE
U. S. DEPARTMENT of AGRICULTURE
PORTLAND, OREGON

PHYSICAL AND CHEMICAL PROPERTIES OF SOME BLUE MOUNTAIN SOILS IN NORTHEAST OREGON

Reference Abstract

Geist, J. Michael, and Gerald S. Strickler.
1978. Physical and chemical properties of some Blue Mountain soils in northeast Oregon. USDA For. Serv. Res. Pap. PNW-236, 19 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Soil properties of 57 forested locations were characterized and categorized by parent materials and vegetation. Properties were compared and interrelated, and their management implications were discussed. Data will serve as a basis for comparison with other soil-vegetation systems and for assessing environmental impacts.

KEYWORDS: Soil properties (physical), soil properties (chemical), soil management, plant-soil relations, volcanic ash soil, Oregon (Blue Mountains).

RESEARCH SUMMARY AND MANAGEMENT IMPLICATIONS

Research Paper PNW-236

1978

Physical and chemical properties of soils in 57 forested locations spanning a wide range in vegetation and climate were characterized. Results were stratified by volcanic ash and basalt parent materials or by overstory tree species. These data did not arise from a random sampling of a defined population of soils and are thereby limited in their extrapolation. But they remain useful to soil scientists, hydrologists, and others in determining management alternatives, assessing management influences, writing impact statements, etc. Virtually all properties are probably related to the productivity of the localities studied; another paper on these relationships is planned.

Volcanic ash materials were found to have high water storage potential and are capable of yielding comparatively large proportions of this water to plants within low soil moisture stress limits (0.1-1.0 bar). This property is important to ecological and productivity considerations since moisture storage is especially critical to growth in areas like eastern Oregon with little summer precipitation.

The bulk densities of ash-derived soils were low and averaged lower than basalt-derived soils at all sampling depths. Densities

Introduction

Quantification of the physical and chemical properties of forest soils is a relatively young effort. Much of the available soil survey data are qualitative, although this is changing as needs for quantitative information increase. This paper reports the results of field investigations and laboratory analyses of soils at 57 study locations in the Blue Mountains in northeastern Oregon. An earlier paper (Geist 1974) contained only data on chemical concentrations for a subset of these locations. The earlier data and that subsequently collected are combined in this paper. Chemical data have also been expressed in units of kilograms per hectare which reflect physical influences on soil chemistry. Thus, this paper provides two reference bases for chemical data and a variety of soil physical data. Portions of both physical and chemical data were also reported by Geist (1973).

Sampling was not done at random within a designated population because soil populations of the Blue Mountains are yet undefined. Thus, the extrapolation of the results are limited to that part of the soil population defined by the parent materials, soils, vegetation, and climatic conditions described in this paper. The data contribute to a better understanding of the soil-vegetation systems studied. This increased knowledge will help resource managers assess and, we expect, predict the various impacts from present and planned land use.

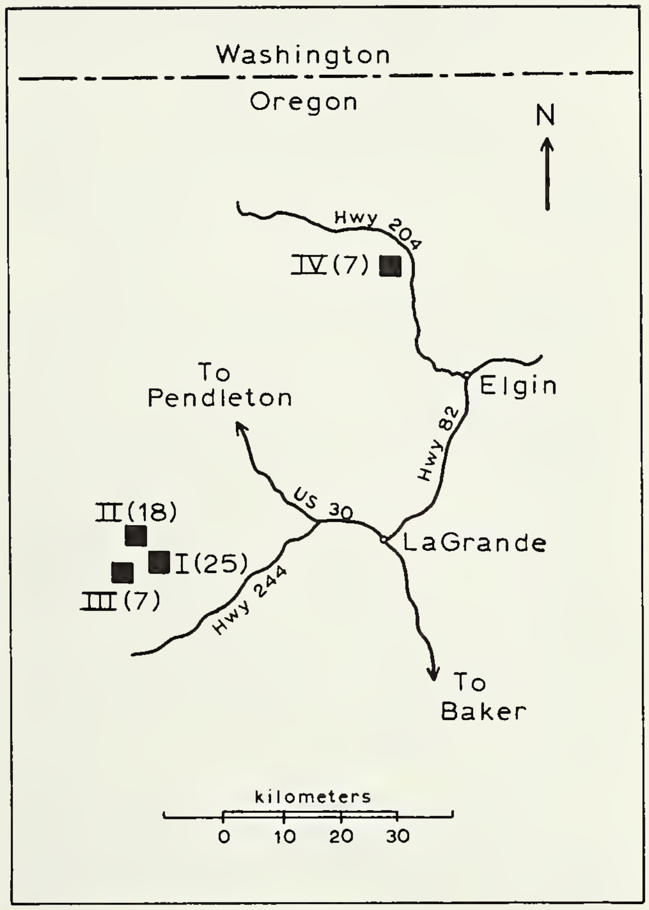


Figure 1.--Study areas I-IV. The number of study locations in each area is shown in parentheses.

Study Area and Soils

Study locations were on forested portions of the Wallowa-Whitman and Umatilla National Forests near La Grande, in Union and Umatilla Counties (fig 1). Most locations (areas I, II, III) occurred in or near the Starkey Experimental Forest and Range. Two soil parent materials dominated: (1) silt-size volcanic ash originating from Mount Mazama eruptions (Harward and Youngberg 1969) and (2) basalt. Mazama ash soils commonly support lodgepole pine (*Pinus contorta* Dougl.), grand fir (*Abies grandis* Dougl. Lindl.), western larch (*Larix occidentalis* Nutt.), Engelmann spruce (*Picea engelmannii* Parry), and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.). Basalt soils support Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and ponderosa pine (*Pinus ponderosa* Laws.), a seral dominant maintained by fire.

Elevations ranged from 1 265 to 1 447 m in areas I, II, and III, and from 1 402 to 1 578 m in area IV.

Precipitation is estimated to range from 50 to 60 cm in areas I, II, and III, and from 90 to 125 cm in area IV.

Soils derived from 50 cm or more of volcanic ash over an older buried soil were of the Tolo (Typic Vitrandepts[1]) and Helter series (Entic Cryandepts). Soils formed primarily from basalt residuum or colluvium were frequently of the Klicker series (Ultic Argixerolls) which range from 50 to 100 cm to bedrock. Shallower soils of similar origin to those described were encountered in the study. These shallower soils were formerly classed within the Tolo and Klicker series concepts,[2] but they are excluded from current series interpretations. Renaming of these soils or recognition of intergrades, etc., has not been resolved. Soil names in this report are uncorrelated and must be considered tentative.

Tolo and Helter soils most commonly occur on north- and east-facing slopes, but they also occur on forested ridgetops or plateaus. Klicker soils generally occupy south and west slopes and ridge margins.

Detailed descriptions of soils are available from the Starkey Soil Survey (Range and Wildlife Habitat Laboratory, La Grande, Oregon); these descriptions are being updated into the new taxonomy. Hence, only general descriptions will be given here.

Tolo soils consist of a silt loam ash layer of weak coarse to thin platy surface structure, grading to massive structure at the buried soil contact. The ash material is soft and very friable throughout. Moist color grades from very dark grayish brown (10 YR 3/2) or dark brown (10 YR 4/3) in surface portions to pale brown (10 YR 6/3) or very pale brown (10 YR 7/4 and 8/3) in lower portions. These moist colors generally lighten markedly during drying.

The buried soils, derived mostly from basalt in areas I, II, and III, are lighter and redder, with 7.5 YR hues common. They have better developed structure which is moderate, medium subangular blocky but occasionally strong fine prismatic, firm to very firm, with textures of silty clay loam to clay loam. Ash layers are 50-100 cm thick within the series, and bedrock exceeds 100 cm. Few coarse fragments occur in the ash layer but rather high percentages may occur in the buried portion.

Helter soils are similar to Tolo soils but have thicker A1 horizons (to 15 cm); and although their elevational occurrences overlap, Helter soils extend to higher elevations. They were common in area IV. Buried portions were mostly of andesitic origin and were probably influenced by loess.

Klicker soils are primarily of basaltic origin but may be ash-influenced in the surface. Surface and subsurface colors are in the redder hues (7.5 and 5 YR). Structure ranges from weak fine platy or weak fine granular in the surface soil to weak or moderate fine subangular blocky in the subsoil. Texture ranges from loam or silt loam in the surface soil to silty clay loam or clay loam in the subsoil. The profile may be strongly affected by gravels and cobbles which are generally more abundant in the lower portion. Influence of coarse fragments is greater on steeper slopes.

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[1] Soil Survey Staff. 1972. Soil series of the United States, Puerto Rico, and the Virgin Islands: Their taxonomic classification. 376 p. Soil Conserv. Serv., U.S. Dep. Agric.

[2] Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. 1960. Soil Conserv. Serv. and Pac. Northwest For. and Range Exp. Stn., USDA For. Serv. Mimeogr., 32 p.

Methods

Sample locations were established within homogeneous vegetation units with uniform surface relief. At each location a bucket auger was used at five random points along a 30-m transect to assess soil depth and to obtain soil samples. Sampling intervals were 0-15, 15-30, 30-60, 60-90, 90-120, and 120-150 cm unless soil depth was limiting. A screw auger was also used to assess total soil depth at the same random points. The five samples from the same depth interval were composited and mixed. Mixed materials were air dried and the soil fraction (less than 2 mm) was separated for chemical analysis. Both size fractions were then weighed.

A soil pit was excavated at each location, soils were described, (Soil Survey Staff 1951) and single, 100-cm^3 undisturbed soil cores were extracted from pit walls at the midpoints of sampling intervals. Cores were wrapped in aluminum foil to avoid drying effects (Forsythe and Vazquez 1973) and refrigerated. Moisture content of cores at 0.1-, 1-, and 15-bar soil moisture stress was determined at room temperature by pressure plate apparatus. Graduated outflow tubes were used to assure equilibrium. Bulk density of the soil fraction was also calculated from cores. The weight and volume of particles greater than 2 mm (coarse fragments) were deducted from core data; a particle density of 2.65 g/cm^3 was assumed. Dry weight of each core was measured after ovendrying. When core samples were not obtained at lower profile depths because of excessive stoniness, data from the nearest depth core in the same profile were used.

Volume percentages of coarse fragments in the soil profile greater than 3-cm diameter were visually estimated when soil descriptions were made. Coarse fragments between 3-cm and 2-mm diameter were included in auger samples and their percentages were initially determined by weight; their volume percentages were then calculated, after allowance was made for soil and larger coarse fragments. Particle sizes of the soil fraction of bucket auger samples were analyzed by hydrometer technique after organic matter was destroyed by hydrogen peroxide.

Chemical analyses of soils included organic matter by the Walkley-Black method, total nitrogen by Kjeldahl method (Jackson 1958), extractable sodium and potassium by flame photometer, and extractable calcium and magnesium by versenate titration (U.S. Salinity Laboratory Staff 1954). Extractable cations of more recent soil samples were determined by atomic absorption spectrophotometer. Available phosphorus was determined by the sodium bicarbonate extraction technique (Watanabe and Olsen 1965), and soil reaction (pH) was measured in 0.01-molar calcium chloride (Black 1965). Carbon-nitrogen ratios were computed; organic matter was assumed to average 58-percent carbon content. Calcium-magnesium ratios were calculated from extractable quantities of each.

When mean nutrient concentrations (percentages or milliequivalents per 100 g) or amounts were calculated for a sample interval, zeros occurring because of shallow soils were not included in the mean but were included for mean cumulative amounts. The same procedure was used in computing water concentrations (percentages) and amounts (centimeters).

Data from physical and chemical soil analyses were grouped by two surface parent materials, ash (regardless of buried soil origin) and basalt, or by one of four overstory timber types: ponderosa pine (PP), mixed conifer (MC), lodgepole pine (LP), and spruce-fir (SF). Except for the SF, this grouping reflected the dominant overstory species. The SF included any study location where Engelmann spruce and subalpine fir were present. The LP and SF groups were strongly associated with ash-derived

soils and the PP, commonly seral to Douglas-fir, with basalt-derived soils. The MC group was most commonly associated with ash, but it also occurred on basalt soils. In this group Douglas-fir or grand fir were commonly dominant or were codominant with PP and western larch.

Results

The strong associations of overstory groups and soil parent materials is illustrated by the following: The PP group contained 18 of 19 soils derived from basalt, the MC had 16 of 20 soils derived from ash, and the 11 soils supporting LP and the 7 soils supporting SF were derived from ash.

PHYSICAL PROPERTIES

Soil textures are closely alined with parent material groups (table 1). Ash soils are dominantly silt loam in texture throughout the ash overburden, then grade into loam in the buried soil. The basalt soils are dominantly loam in the surface and grade into clay loam and clay textures in lower layers.

Clay percentages and associated standard deviations increase downward in both ash and basalt soils, though not at equal rates (table 2). The influence of buried soils is evident at 60-90 cm in ash soils where the mean clay content increases 9 percent over that in the 30- to 60-cm interval. The corresponding increase in basalt soils is 4 percent.

Bulk density is strongly associated with parent material and averages lower in ash soils than in basalt soils at corresponding depths (table 2). Densities increased in both groups at deeper sampling intervals. Variability in bulk density tended to increase with depth but was relatively low in surface layers.

Similar low bulk densities for volcanic ash were reported in Oregon by Ross[3]--0.61-0.68 g/cm^3, Simonson and Shearer (1971)--0.84, and Lincoln

[3]Ross, Richard N. 1971. Snow and soilwater response to logging. M.S. thesis. Colo. State Univ., Fort Collins. 85 p.

Table 1--*Frequency of soil textures by sampling intervals for basalt and ash soils*

Sampling interval	Textural class				Total number of samples
	Clay	Clay loam	Loam	Silt loam	
Centimeters	- - - - - - -	Percent	- - - - - - - -		
Basalt soils:					
0-15	0	0	95	5	22
15-30	0	9	86	5	22
30-60	0	44	56	0	18
60-90	17	33	50	0	6
Ash soils:					
0-15	0	0	0	100	35
15-30	0	0	0	100	35
30-60	3	0	3	94	35
60-90	3	3	59	35	29

Table 2--*Means and standard deviations of some physical properties in ash and basalt soil groups by sampling interval*

Sampling interval	Ash soils[1]			Basalt soils[1]		
	n	$\overline{X}$	s	n	$\overline{X}$	s
Centimeters						
			CLAY CONTENT			
		Percent by weight			Percent by weight	
0-15	35	10	2	22	20	3
15-30	35	9	4	22	22	4
30-60	35	13	6	18	27	6
60-90	29	22	7	6	31	10
			BULK DENSITY OF THE SOIL FRACTION			
		Grams per cubic centimeter			Grams per cubic centimeter	
0-15	35	0.67	0.06	22	0.89	0.09
15-30	35	.66	.07	17	.94	.13
30-60	33	.81	.19	7	1.16	.11
60-90	21	1.08	.17	0	--	--
			TOTAL COARSE FRAGMENT CONTENT			
		Percent by volume			Percent by volume	
0-15	35	3	2	22	24	11
15-30	35	4	7	22	36	17
30-60	35	17	62	19	54	22
60-90	29	29	21	11	65	22

[1] n is the number of soils sampled, $\overline{X}$ the mean, and s the standard deviation. The smaller number of subsoil samples occurs because coarse fragments or bedrock limited sampling.

Laboratory report[4]--0.71-1.15; and elsewhere by Forsythe and Vazquez (1973)--0.80-0.96 g/cm^3, and Martini and Palencia (1975) less than 1.0. Pumice soils of central Oregon also have low bulk densities, ranging from 0.5 to 0.9 (Youngberg and Dyrness 1964). Broadfoot and Burke (1958) found, as we did, that bulk densities frequently increased down the profile; however, they report a range in densities of loam and silt loam soils between 1.20 and 1.39 g/cm^3.

[4] Lincoln Soil Survey Laboratory Report for Soils Sampled in Union County, Oregon, 1960. Laboratory Staff, Soil Survey Laboratory, Soil Conservation Service, U.S. Department of Agriculture, Lincoln, Nebr. 1966. Unpublished report, 48 p.

Coarse fragment percentages (by volume) increased from the surface to lower sampling depths, but the percentages were higher and increased more in basalt soils than in ash soils (table 2). Variability also increased with depth in both groups, notably at 30-60 cm in ash soils. The latter occurred because of the irregular depth of occurrence of the buried soil which contained more coarse fragments.

Mean total soil depth was similar when measured in the soil pit and by screw auger but was lower when measured with the bucket auger (table 3). Soil pits with soil descriptions yield more total information than augers do, however, several augerings can reveal more about depth variability than a single pit excavation can.

Table 3--*Means and standard deviations of total depth of ash and basalt soils measured by 3 methods*

Measuring method	Ash soils[1]			Basalt soils[1]		
	n	$\overline{X}$	s	n	$\overline{X}$	s
		- Centimeters -			- Centimeters -	
Soil pit	35	87	25	22	62	29
Screw auger	35	91	25	22	57	29
Bucket Auger	35	75	16	22	48	24

[1]n is the number of observations, $\overline{X}$ the mean, and s the standard deviation of total depth.

The ash layer averaged 50 cm thick and had a standard deviation of 11 for 35 sampling sites.

Relationships of moisture content to moisture stress, for particles less than 2 mm, differed between ash and basalt soils (table 4). Moisture content of ash soils was higher at 0.1-bar stress and decreased more rapidly to 1-bar stress than in basalt soils. But, from 1- to 15-bar stress, the rate of change in moisture content was similar in both soil groups although the basalt soils were generally higher in moisture content. Data for the 60- to 90-cm increment of ash soils were associated with the buried layers and were similar to that of basalt soils. Moisture content differences in table 4 also reflect these similarities and show that water yield was greater between 0.1- and 1-bar stress in ash soils but was nearly identical among all soils and depths between 1- and 15-bar stress.

Table 4--*Means and standard deviations of moisture content or content differences by volume at 3 moisture stress levels and two moisture stress ranges for ash and basalt soils (soil fraction only)*

Sampling interval	n[1]	Moisture stress level and range[2]									
		0.1 bar		1 bar		15 bar		0.1 to 1 bar		1 to 15 bar	
		$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
Centimeters						Percent by volume					
Ash soils:											
0-15	35	44.7	4.4	18.6	3.7	14.2	3.2	26.1	5.2	4.4	1.9
15-30	35	44.5	5.3	17.5	4.5	12.7	3.2	26.9	5.3	4.9	2.2
30-60	33	43.8	5.2	19.0	4.1	13.4	3.2	24.7	7.0	5.7	2.0
60-90	21	39.2	5.2	26.4	7.2	20.2	6.9	11.8	7.0	6.2	1.7
Basalt soils:											
0-15	22	35.6	2.5	23.6	3.1	18.5	3.0	11.7	3.2	5.1	1.9
15-30	17	33.6	3.1	22.2	4.1	16.9	3.4	11.2	3.9	5.2	1.7
30-60[3]	7	40.3	6.2	30.3	10.0	25.1	10.0	9.9	5.4	5.0	1.3

[1]n is the number of observations.

[2]$\overline{X}$ is the mean, and s is the standard deviation of total depth.

[3]No core samples were obtained below this depth in basalt soils.

Moisture content to moisture stress relationships have been generalized in figure 2 to contrast the basalt-derived materials, whether in basalt soil profiles or in buried portions of ash profiles, with the ash-derived mantle of ash profiles. The curves are approximations which serve to illustrate the overlapping nature of these water relations.

Differences in the potential water storage of soil profiles are evident when data are grouped by timber type (fig. 3). An arbitrary soil depth limit of 90 cm was used with stress limits of 0.1 and 15 bars; calculations include the influences of coarse fragments and depth limitations. SF averaged the highest in storage potential and PP the lowest. Limited depth is more of a factor in the PP data since this group was mostly composed of basalt-derived soils which were shallower than ash-derived soils. The term "potential" is used since these values assume recharge of the profile from winter and spring precipitation. This is highly probable in most years.

Other data available for similar Oregon soils were reported for 0.33- and 15-bar stress. Comparisons show strong similarities to the data reported here. Volume percentages were slightly lower than mean values at 15 bars for some buried soils under ash- and surface basalt-derived materials (see footnotes 3 and 4, p. 4 and 5). Simonson and Shearer (1971) reported that mean available water storage data were unusually high (0.24-0.35 inch per inch of soil) in Tolo soils; they attributed this to the presence of volcanic ash. Data herein support their conclusion. Further, their data show a weighted mean available profile storage of 0.31 inch per inch of soil (0.31 cm/cm), which yields 28 cm of available water in 90 cm of soil and compares favorably with SF data in figure 3. There was no indication that adjustments for coarse fragments in the profile were made in their calculations.

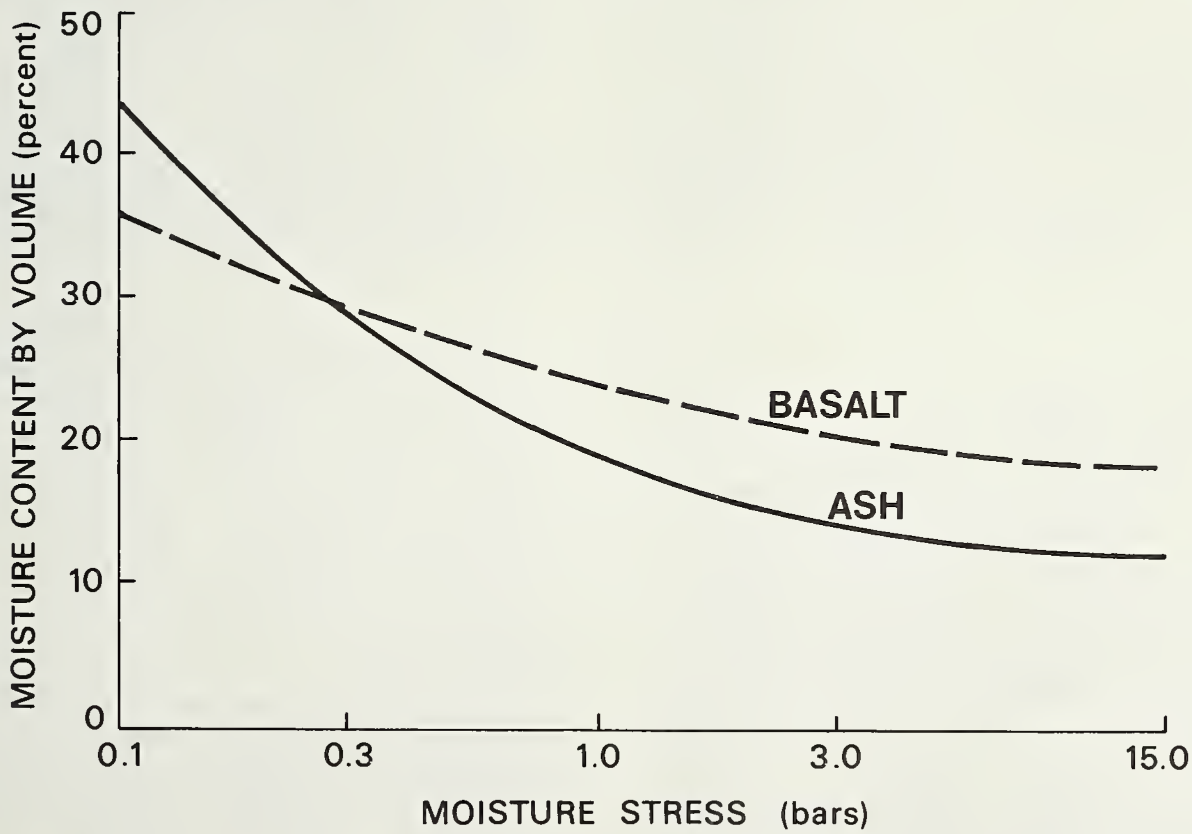

Figure 2.--Generalized soil moisture content and soil moisture stress relationships in volcanic ash- and basalt-derived materials (soil fraction only).

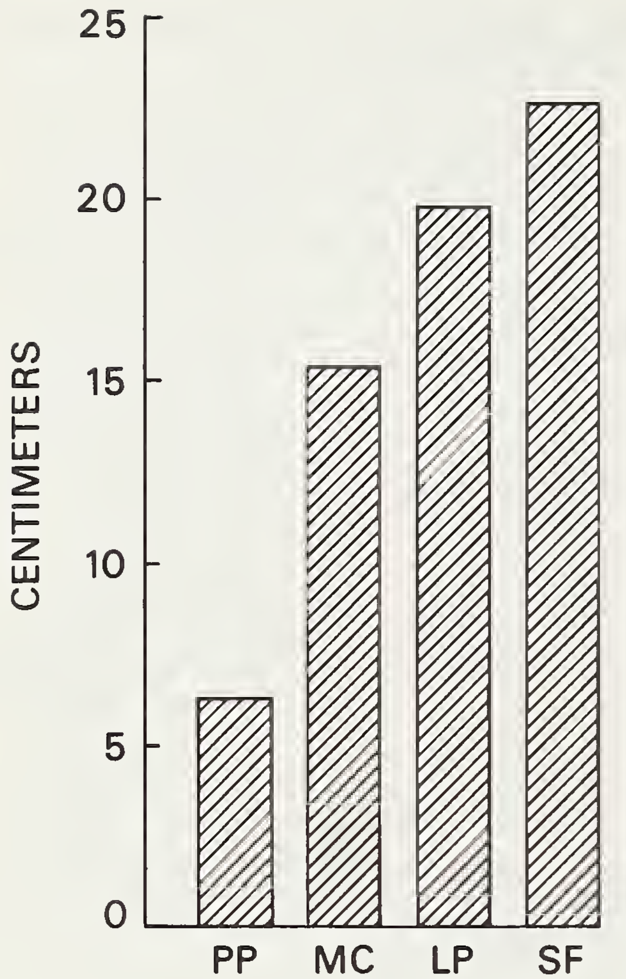

Figure 3.--Centimeters of potential water storage to a depth of 90 cm in the 0.1- to 15-bar moisture stress range for overstory groupings of soils. PP = ponderosa pine, MC = mixed conifer, LP = lodgepole pine, and SF = spruce-fir.

CHEMICAL PROPERTIES

Chemical data are presented as concentrations and amounts per unit area. Concentrations (percent or milliequivalents per 100 g) allow contrasts on a unit weight of the 2 mm and finer fraction only, whereas amounts per unit area reflect all measured soil features (depth, bulk density, etc.)

Concentration data for the PP, LP, and MC groups (tables 5, 6, and 7) include those reported by Geist (1974). The pooled data differed little from earlier values. For this reason, commentary will emphasize data expressed in amounts and will contrast them with concentration expressions. Concentration data paralleled the results included in the Lincoln Laboratory report (see footnote 4, p. 5) for similar soils.

The chemical properties of the A1 horizons of several central Oregon pumice soils studied by Youngberg and Dyrness (1964) were contrasted with our 0- to 15-cm intervals. Their values (milliequivalents per 100 g) were mostly lower in K and P by 50 percent or more, were much lower in Mg, were similar or lower in Ca, but were higher in percentages of organic matter and total nitrogen.

Concentration data for the SF group (table 8) show high levels of total N and organic matter, moderate P, and low extractable cations compared with the other overstory groups. Soil reaction (pH) was comparatively low and reflected the lower cation values. Ratios of C:N and Ca:Mg were similar for SF and other groups.

To avoid duplication of published narrative about concentration data in the PP, LP, and MC groups, we direct the reader to discussions of these groups in Geist (1974).

Martini and Palencia (1975) reported chemical properties of Central American ash soils which frequently agree with data for Blue Mountain ash. They noted good agreement with ash soils of South America, Hawaii, and Japan. Specific departures from data reported here included consistently lower concentrations of available P in their soils, whereas organic matter and total N were frequently higher. The authors reported that phosphorus was the most limiting nutrient and that nitrogen was always limiting in greenhouse studies because of slow mineralization. They drew no analogies to native vegetation influences. Morphologically, their soils

Table 5--*Chemical properties of soils in the ponderosa pine group*

Soil depth	Number of observa-tions	pH ($CaCl_2$)	Organic matter	Total nitrogen	C:N	Avail-able P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
cm			- - - - Percent - - - - -			ppm	- - - - - - Milliequivalents per 100 grams - - - - - -					
						Means[1]						
0-15	19	5.4 ± 0.1	4.08 ± 0.55	0.11 ± 0.01	22 ± 1	44 ± 6	1.4 ± 0.2	0.1 ± 0.0	10.7 ± 0.8	2.6 ± 0.4	14.8 ± 1.0	5 ± 1
15-30	19	5.5 ± .1	2.16 ± .40	.07 ± .01	19 ± 2	31 ± 6	1.1 ± .1	.1 ± 0	9.9 ± .8	3.0 ± .4	14.2 ± 1.0	3 ± 0
30-60	15	5.5 ± .1	1.22 ± .22	.04 ± .00	16 ± 2	24 ± 5	.9 ± .1	.2 ± 0	11.1 ± 1.9	4.5 ± .8	16.7 ± 2.6	3 ± 0
60-90	5	5.6 ± .2	.80 ± .34	.03 ± .01	14 ± 4	17 ± 9	.8 ± .3	.2 ± .1	15.4 ± 6.3	7.8 ± 3.2	24.3 ± 9.5	2 ± 1
						Ranges						
0-15	19	5.0-5.8	2.28-6.83	0.07-0.17	19-24	26-68	0.7-1.9	0.1-0.1	8.3-14.0	1.2-3.9	12.1-19.3	3-7
15-30	19	5.2-5.7	1.28-4.26	.05- .10	13-32	17-68	.5-1.6	.1- .2	7.6-12.7	1.6-4.4	10.9-17.8	2-5
30-60	15	4.9-5.8	.66-2.29	.03- .06	11-26	15-42	.6-1.4	.1- .2	7.0-17.1	2.1-6.7	10.1-24.4	2-3
60-90	5	5.5-5.8	.47-1.23	.02- .04	11-20	7-25	.5-1.1	.1- .3	8.8-22.1	3.6-10.7	13.7-34.0	2-3
						Coefficients of variation (percent)						
0-15	19	4	28	25	7	28	26	0	16	30	15	30
15-30	19	2	39	24	24	40	28	35	17	26	15	20
30-60	15	4	32	14	25	37	25	32	31	32	28	17
60-90	5	2	34	21	25	42	30	37	34	34	32	22

[1]± 95-percent confidence interval.

Table 6--*Chemical properties of soils in the lodgepole pine group*

Soil depth	Number of observa-tions	pH ($CaCl_2$)	Organic matter	Total nitrogen	C:N	Avail-able P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
cm			- - - - Percent - - - - -			ppm	- - - - - - Milliequivalents per 100 grams - - - - - -					
						Means[1]						
0-15	11	5.2 ± 0.1	3.60 ± 0.55	0.09 ± 0.01	24 ± 2	51 ± 9	0.7 ± 0.1	0.1 ± 0	4.2 ± 0.7	1.1 ± 0.1	6.0 ± 0.8	4 ± 1
15-30	11	5.5 ± .1	1.60 ± .17	.05 ± .01	18 ± 1	31 ± 6	.7 ± .1	.1 ± 0	4.3 ± 1.0	1.1 ± .4	6.2 ± 1.3	5 ± 1
30-60	11	5.6 ± .1	.88 ± .08	.03 ± .00	16 ± 2	17 ± 5	.8 ± .1	.2 ± .1	6.7 ± 2.0	1.9 ± 1.5	9.5 ± 3.5	5 ± 1
60-90	11	5.7 ± .3	.59 ± .10	.03 ± .00	13 ± 2	12 ± 4	.8 ± .1	.2 ± .1	10.8 ± 3.4	3.6 ± 1.9	15.4 ± 5.4	3 ± 1
						Ranges						
0-15	11	4.9-5.5	2.29-5.00	0.06-0.11	20-32	33-70	0.6-1.0	0.1-0.1	1.7-5.8	0.9-1.4	3.3-8.0	2-5
15-30	11	5.3-5.7	1.17-2.11	.04- .07	14-21	18-48	.5-1.0	.1- .2	1.7-7.5	.6-2.7	3.3-11.0	2-6
30-60	11	5.2-5.8	.69-1.10	.03- .04	12-20	5-27	.5-1.1	.1- .4	4.0-14.8	.6-8.7	5.6-24.6	2-7
60-90	11	5.1-6.6	.39- .86	.02- .04	9-16	3-26	.6-1.0	.1- .7	5.4-25.0	1.4-12.0	8.7-38.7	2-7
						Coefficients of variation (percent)						
0-15	11	3	23	16	14	26	17	0	25	16	20	21
15-30	11	2	16	15	10	30	22	30	33	52	32	29
30-60	11	3	14	10	17	40	21	52	44	121	55	32
60-90	11	7	25	17	19	46	19	64	46	81	52	41

[1]± 95-percent confidence interval.

Table 7--*Chemical properties of soils in the mixed conifer group*

Soil depth	Number of observations	pH ($CaCl_2$)	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
cm		- - - - - Percent - - - - -				ppm	- - - - - - Milliequivalents per 100 grams - - - - - -					
						Means[1]						
0-15	20	5.6 ± 0.1	3.43 ± 0.46	0.10 ± 0.01	20 ± 1	63 ± 12	1.4 ± 0.2	0.1 ± 0	8.2 ± 1.5	1.5 ± 0.3	11.2 ± 2.0	6 ± 1
15-30	20	5.5 ± .1	1.93 ± .29	.06 ± .01	18 ± 1	36 ± 9	1.1 ± .1	.1 ± 0	6.8 ± 1.6	1.3 ± .3	9.3 ± 2.0	5 ± 1
30-60	20	5.4 ± .1	1.37 ± .27	.04 ± .01	18 ± 2	22 ± 6	1.0 ± .1	.2 ± 0	8.0 ± 1.5	2.1 ± .4	11.2 ± 2.0	4 ± 1
60-90	12	5.3 ± .2	.61 ± .06	.03 ± 0	12 ± 1	12 ± 3	.8 ± .1	.3 ± 0	9.9 ± 0.8	3.8 ± .4	14.8 ± 1.1	3 ± 0
						Ranges						
0-15	20	5.2-5.9	1.73-5.43	0.06-0.16	17-25	22-111	0.8-2.2	0.1-0.1	4.6-15.7	0.9-3.2	6.5-21.1	4-10
15-30	20	5.1-5.8	1.14-3.48	.04- .11	13-21	11- 76	.5-1.6	.1- .2	2.3-14.8	.6-2.6	3.5-18.6	4-9
30-60	20	4.7-5.7	.79-3.23	.03- .10	13-33	8- 47	.5-1.6	.1- .3	4.0-14.4	1.1-4.7	6.3-20.0	2-7
60-90	12	4.7-5.7	.44- .75	.03- .04	9-16	6- 21	.6-1.1	.2- .4	8.5-11.6	2.7-5.1	12.0-17.7	2-4
						Coefficients of variation (percent)						
0-15	20	3	29	28	10	39	29	0	40	49	38	27
15-30	20	3	32	31	13	55	26	22	52	49	46	31
30-60	20	4	43	38	26	56	25	36	41	43	38	30
60-90	12	7	16	14	18	42	16	26	12	18	11	19

[1] ± 95-percent confidence interval.

Table 8--*Chemical properties of soils in the spruce fir group*

Soil depth	Number of observations	pH ($CaCl_2$)	Organic matter	Total nitrogen	C:N	Available P	Extractable cations					Ca:Mg
							K	Na	Ca	Mg	Total	
cm		- - - - - Percent - - - - -				ppm	- - - - - - Milliequivalents per 100 grams - - - - - -					
						Means[1]						
0-15	7	4.8 ± 0.3	7.89 ± 2.71	0.22 ± 0.07	21 ± 2	45 ± 21	0.6 ± 0.2	0.1 ± 0.0	3.0 ± 1.8	0.8 ± 0.3	4.4 ± 2.1	4 ± 2
15-30	7	5.0 ± .2	4.70 ± 1.61	.16 ± .07	18 ± 3	21 ± 10	.5 ± .3	.1 ± 0	1.8 ± 1.5	.6 ± .3	3.0 ± 1.9	3 ± 2
30-60	7	5.0 ± .1	2.34 ± 1.06	.09 ± .04	14 ± 1	17 ± 7	.4 ± .3	.1 ± 0	1.6 ± 1.0	.6 ± .2	2.7 ± 1.4	2 ± 1
60-90	7	4.7 ± .3	1.02 ± 0.36	.06 ± .02	10 ± 1	26 ± 11	.6 ± .2	.1 ± 0	6.1 ± 2.7	2.0 ± .8	8.8 ± 3.5	3 ± 1
						Ranges						
0-15	7	4.5-5.3	4.98-13.36	0.14-0.36	17-24	13-80	0.4-1.1	0.0-0.1	0.7-5.5	0.2-1.0	1.8-7.5	1-7
15-30	7	4.7-5.3	2.48-8.00	.07- .29	15-23	10-42	.3-1.1	0.0- .1	.3-4.2	.2- .9	.9-5.9	1-5
30-60	7	4.8-5.3	.99-4.18	.05- .16	12-17	10-29	.2-1.0	.1- .1	.3-3.5	.2- .9	.8-4.9	1-4
60-90	7	4.3-5.2	.60-1.65	.04- .08	8-12	12-46	.4- .9	.1- .2	2.4-9.9	1.0-3.5	3.9-14.1	2-4
						Coefficients of variation (percent)						
0-15	7	6	37	36	11	51	45	44	64	36	51	54
15-30	7	4	37	46	16	51	60	44	90	46	67	58
30-60	7	3	49	49	11	44	64	0	71	42	57	40
60-90	7	6	39	28	13	47	30	38	48	44	44	23

[1] ± 95-percent confidence interval.

have much deeper ash layers with thick (50+-cm), dark, A horizons. They sampled by horizon rather than fixed depths which partially accounts for differences in some chemical properties.

The appearance and hence interpretation of results can be affected by method of expression. Little difference in relationships among group means is seen when concentrations of organic matter are compared with amounts per unit area (fig. 4A versus 4B). But there are notable differences among group means when concentrations of Ca+Mg+K at depth increment 4 are compared with amounts at 90 cm (fig. 5A versus 5B). This is due to interacting effects contributed by coarse fragment percentages, bulk densities, total depth, and texture of the soils. Calcium and magnesium dominated the extractable cations, and both closely followed the trends shown for the summed cations.

This clouded the dynamics of potassium values, so they have been separated and reported with the nitrogen and phosphorus data (table 9). A decline and rise progressing from the first through the third sampling interval (partially due to sampling interval thickness) occurred in all properties except for total N and available P in the PP group. Amounts of N further declined in the fourth increment for all groups; P and K also declined in all but the SF

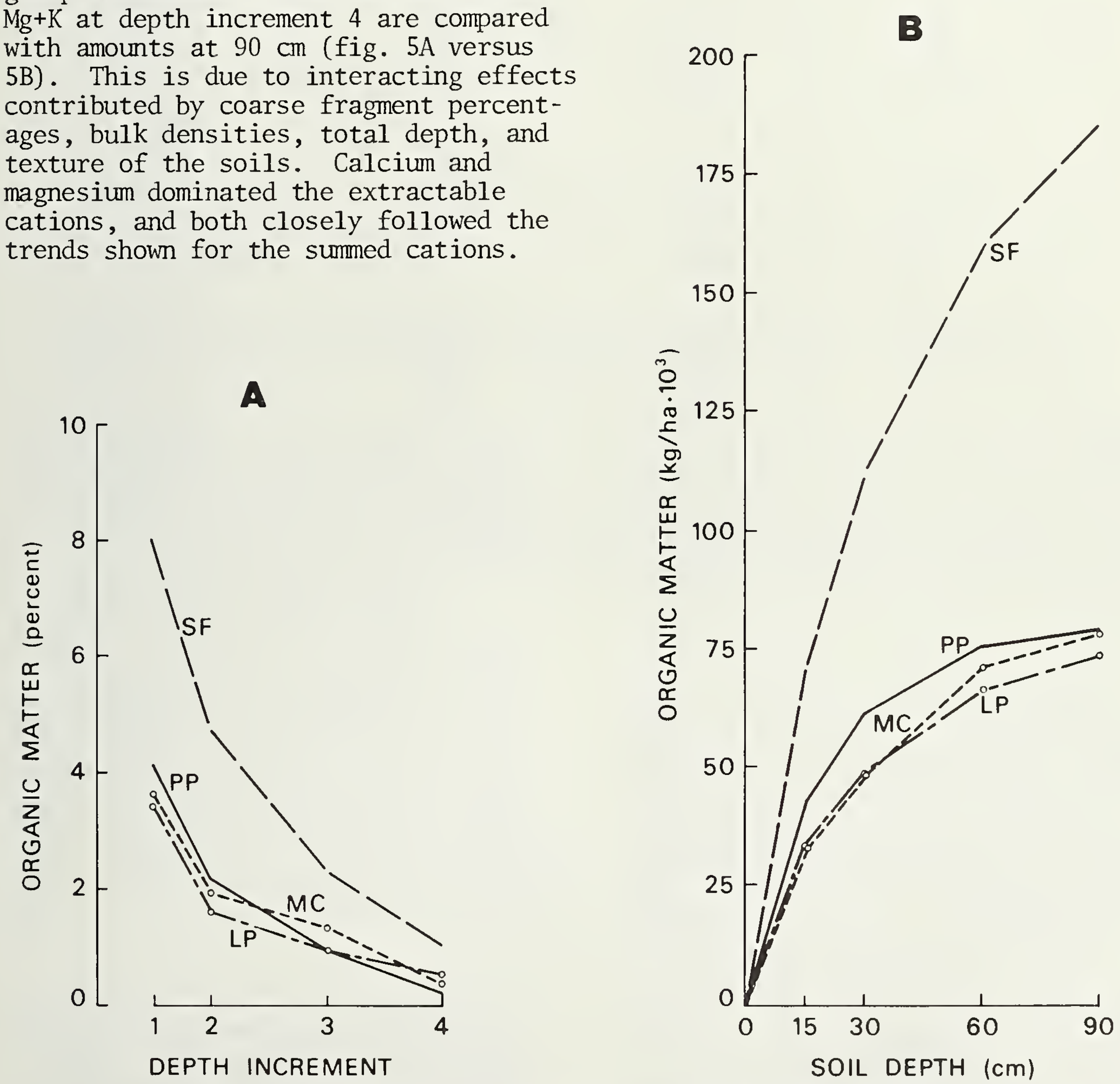

Figure 4.--Mean percentages (A) and cumulative amounts (B) of organic matter by overstory groups. PP = ponderosa pine; MC = mixed conifer; LP = lodgepole pine; and SF = spruce-fir.

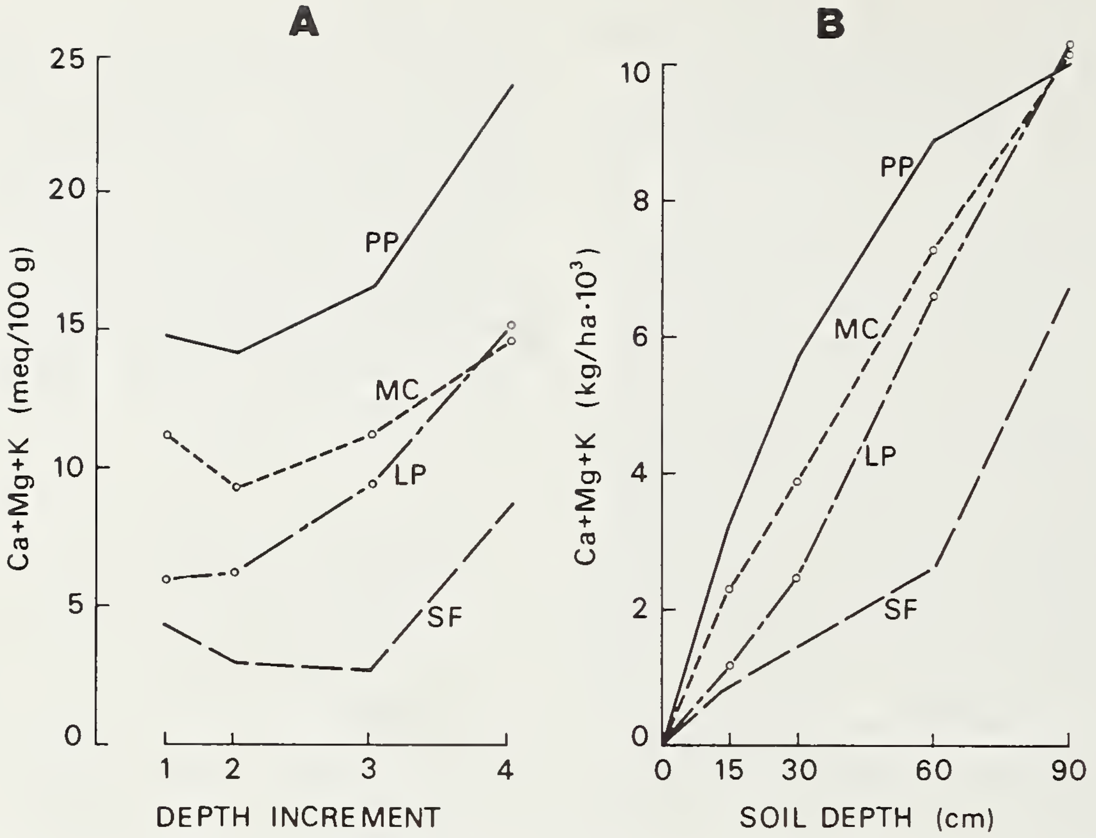

Figure 5.--Mean extractable cation contents (A) and cumulative amounts of cations (B) by overstory groups. PP = ponderosa pine; MC = mixed conifer; LP = lodgepole pine; and SF = spruce-fir.

group where amounts increased. Although not shown in table 9, the decline and increase and decline trends were followed by summed cations and organic matter, except that summed cations in the 60-90 interval rose sharply in the SF group and slightly in the LP. Means for cumulative total N were similar in all but the SF group, which was much higher. The SF group was highest in total available P (although strongly subsoil distributed) but lowest in total extractable K. The MC group had the highest total extractable K and was near the high in total available P. Lowest total available P occurred in the PP group.

Cole et al. (1967) reported values of 2 809, 3 878, and 234 kg/ha for total N, extractable P, and extractable K in 60 cm mineral soil derived from glacial outwash in the Puget Sound Basin. Their soil supported a 36-year-old stand of second-growth Douglas-fir. Compared with data in table 9, the glacial soil was higher in P, lower in extractable K, and higher in N except for the SF group.

In comparisons of soils supporting 30-year-old stands of red alder-Douglas-fir with only Douglas-fir in southwestern Washington, Tarrant and Miller (1963) found 4 225 and 3 174 kg of total N per hectare, respectively. These values were for the total of forest floor and mineral soils to 91 cm from sites having a history of at least three fires. The values were higher than in our study soils under mature stands of PP, LP, and MC.

Williams and Dyrness (1967) sampled soils in the Cascade Range under true fir and hemlock stands. Their data, reported by geographic provinces, showed mean values ranging from 5 077 to 13 456 kg of total N

Table 9--*Mean amounts of nitrogen (N), phosphorus (P), and potassium (K) in overstory groups by sampling interval and summed to 90-cm depth*

Group and sampling increment	Observations	Total N[1]		Available P[1]		Extractable K[1]	
		$\overline{X}$	s	$\overline{X}$	s	$\overline{X}$	s
Centimeters		Kilograms per hectare					
Ponderosa pine:							
0-15	19	1 151	245	47	16	608	204
15-30	19	588	112	29	14	404	168
30-60	17	553	372	29	25	446	359
60-90	9	234	241	12	14	244	303
Total (0-90)[2]	19	2 345	--	108	--	1 527	--
Lodgepole pine:							
0-15	11	830	162	48	13	273	44
15-30	11	494	69	30	9	266	67
30-60	11	649	258	32	14	596	219
60-90	10	339	298	13	12	420	358
Total (0-90)[2]	11	2 281	--	122	--	1 517	--
Mixed conifer:							
0-15	20	935	251	62	29	520	149
15-30	20	532	177	33	22	376	137
30-60	20	690	346	37	30	625	322
60-90	17	400	321	18	20	409	335
Total (0-90)[2]	20	2 497	--	147	--	1 869	--
Spruce fir:							
0-15	7	1 970	624	41	21	229	111
15-30	7	1 410	585	19	10	184	110
30-60	7	1 883	913	34	14	342	196
60-90	7	1 445	548	63	28	571	143
Total (0-90)[2]	7	6 708	--	157	--	1 326	--

[1] $\overline{X}$ is the mean and s the standard deviation.

[2] The reason for the disparity between 0- to 90-cm means and totals of interval means is that zero values associated with locations lacking soil in the 30- to 60- or 60- to 90-cm increments were included in the 0- to 90-cm mean but were not included in interval means.

per hectare, 22 to 56 kg of available P per hectare, 283 to 1 167 kg of extractable K per hectare for soil depths extending to bedrock or stony layers but excluding the forest floor. Thus, their soils were higher in total N and lower in extractable P and K than ours.

The amount of total N (1 981 kg/ha) in 61 cm of a typical central Oregon soil of pumice origin (Youngberg and Dyrness 1964) was similar to means in all but the SF group. Available P (31 kg/ha) was about two-thirds and extractable K (614 kg/ha) about half the mean levels reported in this paper, except that extractable K in the SF group exceeded that of the pumice soil by only 140 kg/ha. Youngberg and Dyrness commented that 61 cm of soil in western Oregon on a medium site supporting Douglas-fir contains 8 960 kg/ha of total N, and other nutrients are correspondingly higher.

Discussion

The weaker structural development and larger percentage of silt-size

particles in surface layers of ash soils indicate a higher topsoil erosion potential than for basalt-derived materials. In our study area, precipitation principally occurs as winter snow and gentle spring rain; thunderstorms are comparatively infrequent. Thus, neither material is highly vulnerable under natural cover conditions, but, with disturbance, both soils readily erode. Channeling of surface runoff leads to varying degrees of rill and gully formation. A rather unique property of ash layers reduces their susceptibility to water erosion. Until soil pores are saturated, soil particles tend to lock together like a jigsaw puzzle. It is common to see undisturbed walls of soil pits, several years old, showing very minor side sloughing. Under dry conditions, the exposed and disturbed ash layer is highly susceptible to wind erosion.

A patchy and variable degree of water repellency was noted in several ash profiles. This has been observed in ash soils elsewhere (Martini and Palencia 1975) but is not unique to ash soils. Some workers think that the degree of repellency, at times, is positively correlated with dryness in the field prior to rewetting.

Surface runoff from the basalt-derived soils under natural conditions is moderate because of limited depth and moderate infiltration and internal drainage, whereas runoff from ash soils is lower because of higher infiltration rates and rapid internal drainage in the ash overburden. Buried basalt-derived materials retard internal drainage to a degree depending on their textural and structural properties. Surface runoff from either soil will usually increase with surface disturbance.

Observations of roadside cuts indicate that the most frequent slumping of ash soils occurs when finer textured buried layers become water saturated and cannot support the ash materials above. This occurs even though the moisture percentage of the ash may be as high or higher than lower materials. When internal water movement during the wetting process is retarded at the ash-buried soil interface or at bedrock, a lubricated contact plane results and creates a condition conducive to soil slippage. The hazard for both slumps and slippage increases as the slope gradient increases.

The uniformity of surface bulk density, particularly in volcanic ash soils, has practical application since it offers a fairly stable benchmark for assessing soil compaction. But displacement of the surface soil in logging and associated operations increases the natural variability of the new surface and increases the difficulty of measuring compaction. The number of samples required to estimate the mean density with the same accuracy is greater after disturbance than before.

Soil bulk densities are commonly assumed to be higher than 1.0 g/cm^3. If such an assumption was applied to the surface layer of study soils, it would lead to errors of 30 percent or more. Too, soil scientists frequently assume that an acre-6 inches of soil weighs 2 million pounds. Such an assumption for ash soils can lead to errors of 50 percent since the assumed value corresponds to a bulk density of 1.47 g/cm^3. Broadfoot and Burke's (1958) tables for estimating bulk density give values which are too high and should not be applied to the study soils or others with significant ash influence.

An average particle density of 2.65 g/cm^3 was assumed for the soil materials studied. Ross (see footnote 3, p. 4) found particle densities between 2.49 and 2.75 g/cm^3 in northeastern Oregon. Youngberg and Dyrness (1964) reported values that ranged from 2.35 to 2.83 g/cm^3, and averaged 2.61, for pumice in central Oregon. Thus, it appears our assumption was reasonable and did not significantly influence the data presented.

Coarse fragments can strongly influence site productivity and are an important factor to note in inventory efforts. Coarse fragments dilute soil nutrients on a volume basis. When present in the surface soil, they can improve the effectiveness of infrequent growing season precipitation but detract from total water storage capacity. We consider water storage capacity to generally be more important to vegetation growth in the Blue Mountains. Hence, coarse fragments, regardless of profile position, are considered a negative influence on productivity of Blue Mountain soils.

Ash soils store about twice the volume of water that basalt soils store between 0.1- to 15-bar stress. Most of the water stored in ash soils is available to plants in the low stress range (0.1- to 1-bar). Similar relationships were reported for pumice soils (Youngberg and Dyrness 1964, Packard 1957). Thus, plants should experience comparatively little soil moisture stress in ash soils during early periods of growth.

Basalt soils yield water in a fairly linear fashion between the stress extremes measured; however, surface soils with greater ash influence assume a more curvilinear relationship. It becomes important, then, to assess the degree of ash influence when water relations of basalt soils are evaluated.

The effect of the factors discussed above was best illustrated by the comparisons of water storage capacity by overstory group (fig. 3). The strong association of ponderosa pine for low moisture sites is evident. Most of these sites were also associated with southern or southwest exposures which adds to their droughty nature.

Water-holding relationships reported by Broadfoot and Burke (1958) for silt loam (medium texture) soils underestimate values found here for volcanic ash materials. Thus, as noted for bulk densities, serious errors can result from applying their data to water storage computations in our study soils.

High values for organic matter and total N are strongly associated with the SF group. Spruce-fir stands usually occur on deep soils at higher elevation and precipitation zones, and they visibly appear more productive than the other three groups. Thus, the vegetative and environmental factors are confounded and potential cause-effect relationships cannot be drawn. Low values for total cations and pH suggest that higher precipitation is providing more profile leaching and/or lower base cycling occurs in SF vegetation than in other soils and vegetation.

In all overstory groups, organic matter percentages decline about 50 percent for each step down in sampling interval. About two-thirds of the total organic matter and nitrogen present in the upper 90 cm of soil of PP, MC, and LP groups occurs in the top 30 cm. The distribution is less skewed in the SF group where about half the organic matter and total nitrogen occurs in the upper 30 cm. Hence, the top 30 cm (1 foot) of soil contains a disproportionately large nutrient reservoir. Since nitrogen is always implicated in nutrient deficiencies of soils in the Blue Mountains (Geist 1976), this quantification lends support to the adage: "Protect your topsoil." Phosphorus, too, is most often highest in the surface layers although some buried soil layers contain fairly high quantities. Again, these results encourage maintenance of topsoil.

The disparities in interpretation between expressions in concentrations and amounts of some chemical properties raise questions about which expression relates most meaningfully to plant nutrition and production. It seems logical that concentrations would be

more important to shallow-rooted plants. If this is true, size and kind of rooting pattern are important factors influencing adaptability of plants to sites. Mature plants with well-developed, deep root systems would be more affected by total amounts of nutrients in the soil.

Debate over concentrations versus amounts may be unnecessary when comparing fertility of soils with similar bulk densities. Since many soils have surface bulk densities over 1.0 g/cm^3, however, a sizable error can occur when these soils are contrasted with soils of low densities. This point was stressed by Youngberg and Dyrness (1964) who preferred expressions of amount per unit area. The dilution effect of low bulk density is chemically similar to the effect of a high content of coarse fragments but is physically dissimilar because low bulk density is accompanied by high porosity. The latter factor is one reason why moisture percentage on a volume basis is favored over a weight basis (Packard 1957).

The above disparity also raises questions about how soils should be sampled for greenhouse growth experiments. Should one include coarse fragments? Should soil comparisons be made on an equal weight basis or equal volume basis? The answers are partially dependent on objectives; either approach alone may be unsatisfactory. Where bulk densities are similar, a fixed weight basis of comparison seems justified. With differing densities, a means of discounting weight differences should be used with equal volumes of potted soil.

Expressing chemical factors on an amount per unit area basis may also be preferred since this allows direct summation of data for sampling intervals. Thus, depth factors are easily changed for studying plant relationships. Allowance for physical influences is also easily made when chemical units are kilograms per hectare.

Sampling depth control is imperative to collection of representative soils samples in view of sharp gradients in chemical and physical properties down the profile. This is particularly true in cases where repetitive sampling is involved and fixed depths are used.

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Appendix

The following examples of applications of chemical and physical data apply to both current and future problems of resource managers.

Example 1:

Find the centimeters of plant available water stored in a soil segment between specified soil water stress limits (we have assumed that field capacity and permanent wilting occur at 0.1- and 15-bar stress, respectively):

Centimeters of water storage = water content percentage difference for stress range/100 x soil depth in cm x soil volume percentage;

i.e., for 30 cm ash soil between 0.1 and 15 bars stress with 10 percent coarse fragments:

8.9 cm water = 45-12% by volume/100 x 30 x 100-10%/100.

The 8.9 cm represents about 8.9/30 x 100 or 30 percent of the soil section volume as storage capacity for the *stated stress limits*. This kind of calculation is useful to watershed personnel for figuring water balance relationships. This example can also be used to compute loss of soil moisture caused by erosion or displacement of soil from scalping or slash piling operations.

Example 2:

Find the amount of nutrients in a given soil segment:

Amount of nutrients in kg/ha = meq/g x meq weight in grams x depth in cm x mass of ha-cm water x bulk density x soil volume percentage.

One ha-cm water has a mass of 10^5 kg; this is similar to the concept for weight of an acre-foot of water. Find kg/ha K in 15 cm of ash surface soil, with a 20-percent volume of coarse fragments with a soil bulk density of 0.7 g/cm^3, where the soil contains 1.2 meq K/100 g:

0.012 x 0.0391 x 15 x 100,000 x 0.7 x 0.8 = 394 kg K/ha.

As we learn more about timber or forage nutrient requirements, such calculations will be more important for assessing or ranking the fertility and productivity of management units.

Example 3:

A catchment basin contains 110,000 kg (121.2 tons) of sediment material and is estimated to contain 20 percent ash and 80 percent basalt-derived surface soil with natural bulk densities of 0.7 and 0.9, respectively. The watershed associated with the catchment has an area of 20 ha; however, the actual areas of the sediment sources were 0.1 ha of an ash soil and 0.3 ha of basalt soil. Neither soil contained over 5 percent coarse fragments. The sediment came from sheet erosion which was assumed to be equally distributed over the source areas. (This assumption makes the problem simple but is seldom justified in practice.) Calculate the thickness of soil lost from the two eroding areas:

cm of soil = (sediment mass in kg)(sediment percentage)/(mass of ha-cm of water)(bulk density of native soil) x 1/eroded area in ha.

(Coarse fragments equal to 10 percent or more by volume in the native soil should be accounted for in the calculations, whether they were left behind on the erosion site or were present in the sediment basin. Sizable errors can result if these fragments are ignored.)

For the ash soil:

$$\frac{110{,}000 \times 0.2}{100{,}000 \times 0.7} \times \frac{1}{0.1} = 3.1 \text{ cm thickness.}$$

For the basalt-derived soil:

$$\frac{110{,}000 \times 0.8}{100{,}000 \times 0.9} \times \frac{1}{0.3} = 3.3 \text{ cm thickness.}$$

Analyses of the sediment would allow calculations of the nutrients lost because of erosion. If the eroded area was monitored with graduated stakes, measured readings of soil loss could be compared with calculated values. Frost heaving or other disturbances often make the use of such stakes difficult, but they can be advantageous in some circumstances.

GPO 986-312

Geist, J. Michael, and Gerald S. Strickler.
1978. Physical and chemical properties of some Blue Mountain soils in northeast Oregon. USDA For. Serv. Res. Pap. PNW-236, 19 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Soil properties of 57 forested locations were characterized and categorized by parent materials and vegetation. Properties were compared and interrelated, and their management implications were discussed. Data will serve as a basis for comparison with other soil-vegetation systems and for assessing environmental impacts.

KEYWORDS: Soil properties (physical), soil properties (chemical), soil management, plant-soil relations, volcanic ash soil, Oregon (Blue Mountains).

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1978. Physical and chemical properties of some Blue Mountain soils in northeast Oregon. USDA For. Serv. Res. Pap. PNW-236, 19 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Soil properties of 57 forested locations were characterized and categorized by parent materials and vegetation. Properties were compared and interrelated, and their management implications were discussed. Data will serve as a basis for comparison with other soil-vegetation systems and for assessing environmental impacts.

KEYWORDS: Soil properties (physical), soil properties (chemical), soil management, plant-soil relations, volcanic ash soil, Oregon (Blue Mountains).

The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

Within this overall mission, the Station conducts and stimulates research to facilitate and to accelerate progress toward the following goals:

1. Providing safe and efficient technology for inventory, protection, and use of resources.
2. Developing and evaluating alternative methods and levels of resource management.
3. Achieving optimum sustained resource productivity consistent with maintaining a high quality forest environment.

The area of research encompasses Oregon, Washington, Alaska, and, in some cases, California, Hawaii, the Western States, and the Nation. Results of the research are made available promptly. Project headquarters are at:

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